# Flood risk on human settlement and agriculture along Luvuvhu River basin

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### Abstract

Research has been done along Luvuvhu River at Makovha village to determine the safe locations of durable property and agriculture from the floods. Log-Pearson Type III distribution has been used to compute the return periods of annual peak discharges. The reasonableness of the computed return periods have been confirmed by measuring the extent of flooding by the extreme floods. Extreme floods have been shown to flood differential extents of the riparian zone and its neighbourhood. The study established that the safe location of durable property such as human dwellings with minimum flood threats should be beyond the 1:100 year flood mark. However, the flood line of agriculture in the neighbourhood of the riparian zone should be based on the 1:50 year flood mark. With proper forecasting to avoid uncertainties of extreme floods this restriction can be relaxed provided proper soil management techniques are used.

**Keywords**: Flood risk, agriculture, Luvuvhu River.

## 1 Introduction

Occasional and destructive flood events have occurred in the Luvuvhu River basin. The most notable of all these since 1970 occurred in the years 1977 and 2000. The floods have each time resulted in major destruction to human settlements and agriculture which are the widespread land use types in the area. This has created the need to investigate the extent to which the floods pose risks to agriculture and human settlements along the Luvuvhu River basin. Makovha village along the Luvuvhu River basin has been chosen for the study because the land use types in the area are dominantly human settlements and subsistence agriculture in the neighbourhood of the riparian zone. Cultivating crops in the neighbourhood of the riparian zone is a common practice due to the availability of water and high fertility of the soil deposited by runoff from the surrounding agricultural farms. Floodplains are generally valuable to man because their soils are generally fertile and because such areas are flat and easy to use (Luna, 1997). The year 2000 flood inundated the neighbourhood of the riparian zone and destroyed all the crops. Riparian zones being highly vulnerable to floods and soil erosion require proper planning of any practical economic or social activity within it or its neighbourhood. This saves them from threats associated with floods.

In Southern Africa in general, floods are often sudden and devastating in their magnitude and unexpected. The public in Southern Africa view flood events as random or freak events, with seemingly little chance of predicting their position, magnitude and recurrence (Van Bladeren and Zawada, 1998).

Floods can be described in terms of their statistical frequency, which can be determined by either using the method of plotting positions to obtain an empirical cumulative distribution, or theoretical probability distributions. This is done by the use of historical data of flood events from stream flow gauges at specific localities to delineate the extent and recurrence interval of flooding. In particular, the statistical approach predicts the flood magnitude and the return period (recurrence interval) of each flood event. Numerous distributions have been suggested on the basis of their ability to fit plotted data from streams (Linsley, 1988). This is very important as most probability distributions give discharge-time relationships which differ greatly from one another, particularly for large floods. The reliability of the chosen distribution is guaranteed by using long period data.

Linsley (1988) reports flow conditions that have in practice been precisely fitted by some of the most commonly used theoretical probability distributions to date. Annual maximum hourly or daily amounts ordinarily conform to Gumbel, Log Pearson Type III, Log-normal or Gamma distribution. In humid areas, where the mean is high, monthly, seasonal or annual totals approximate a normal distribution. In drier areas a skew distribution such as the Log Pearson, Log-normal or Gamma gives a better fit. The predictive potentials of these theoretical distributions vary with catchments of different characteristics.

The two shortcomings of theoretical probability distributions are: the site of interest is seldom near a gauging station and flow records are often too short for reliable estimates of higher levels of statistical parameters, i.e. standard deviation, and skewness, implying low reliability of estimates of large recurrence interval floods. This gives the reason for limited testing of the various theoretical probability distributions in South Africa. Complete flow records have been limited and unreliable. Gauging stations dating as far back as 1901 either have gaps in the records or were closed down at some point for various reasons. For years, a number of stations had limited gauging capacity and most of the annual maxima exceeded the calibration capacity (Alexander, 1990).

As a result of the insufficient records, not much has been done on flood frequency analysis in South Africa. However, for the few studies that have been done Log Pearson Type III distribution has been found to perform well with all available South African River flow data (Alexander, 2000). This distribution has been recommended for widespread use in United States of America (USA) and United Kingdom (UK) after extensive testing in a number of catchments. It has therefore been adopted in this study to estimate the return period of the flood events recorded at Makovha village along the Luvuvhu River.

Log-Pearson Type III distribution is a three-parameter distribution. The parameters include the mean, the standard deviation and the skew coefficient of the logarithms of the annual maximum peak flows. It is a higher parameter distribution as compared to the other distributions and therefore explains much more about the data than the lower parameter distributions. In general, the more parameters a distribution has, the better it fits a set of data and the more flexibility it has for fitting many different sets of data. One of the limitations of Log Pearson Type III is that the available Harter's Tables have their skew coefficient values lying between -3.0 to 3.0, which limits the return period to a maximum of 200 years.

The Log Pearson Type III distribution is defined as:

$$LogQ_T = M + K_T S \tag{1}$$

where, $Q_T$ is the peak discharge for the selected recurrence interval T; M is the mean of the logarithms of the annual peaks; $K_T$ is the Pearson Type III frequency factor; and S is the standard deviation of the logarithm of the annual peak discharge.

## 2 Materials and methods

The stream flow data for 50 years from the year 1950 to 1999 from a stream flow gauging station along the Luvuvhu River in the neighbourhood of Makovha village was collected from the Department of Water Affairs and Forestry (DWAF). The highest stream flow value was then selected for each year to constitute the annual maximum series required for application in Log Pearson Type III distribution. The parameters of the distribution including the mean (M), the standard deviation (S) and the skew coefficient (G) were computed from the following formulae respectively:

$$M = \frac{\sum X}{N} \tag{2}$$

$$S = \sqrt{\frac{\left(\sum X^2 - \frac{\left(\sum X\right)^2}{N}\right)}{N-1}} \tag{3}$$

$$G = \frac{N^2\left(\sum X^3\right) - 3N\left(\sum X\right)\left(\sum X^2\right) + 2\left(\sum X\right)^3}{N(N-1)(N-2)S^3} \tag{4}$$

where, $\sum X$ is the sum of Log $Q_T$; and, N is the number of observations.

Equation 1 was used to compute $K_T$, which was then used together with G to determine the return period for each peak discharge from the Harter's Tables for Log-Pearson Type III distribution.
Local residents in the neighbourhood of the study site were interviewed to establish the extent of each extreme flood in order to estimate the corresponding flood lines associated with each flood. Tape measure together with the range rods were used to measure the distances of the flood lines associated with major flood events from the river and the distance where the planting of crops begins from the river bank. The distance of the first line of settlements away from the river was also measured with the tape measure and the range rods. The hydrological data on flood occurrences was confirmed by interviewing the local community on when the destructive floods occurred.

## 3 Results and discussion

The computed parameters of Log Pearson Type III distribution given in Table 1 were used to determine the return periods for each annual peak discharge given in Table 2. Most (98%) of the annual peak discharges in the 1950-1999 hydrological data had return periods ranging from <1-50 years (Table 2). Floods of return periods in excess of 50 years such as that of 1977 are considered as extreme and risky floods because of their destructive tendencies stretching beyond the riparian zone. Annual maximum flows of return periods greater than 50 years have been infrequent at Makovha village along the Luvuvhu River basin. Only 2% of the annual maximum peak flows had return periods greater than 50 years from the 1950-1999 hydrological data (Table 2). Since large and extreme floods are uncommon along the riparian zone of Luvuvhu River at Makovha village, agriculture in the neighbourhood of the riparian zone can be practiced safely without threats of flooding and submergence during periods of no large and extreme floods provided proper soil management measures are taken to minimize soil erosion. The scheduling of these agricultural activities must take into account when the last large or extreme flood occurred. This helps in determining when the next large or extreme flood is likely to recur. In between agricultural activities can continue normally. The same can be said of human settlements if their life spans are less than the return periods of the large and extreme floods.

The outcomes of interviewing the local community indicate that they had major floods in the years 1977 and 2000. Although the stream flow data for the year 2000 (February) is missing, from the hydrological information available, the year 2000 floods were of high discharge magnitude and intensity. The gauging station was submerged in water. From the 1950-1999 records, the year 1977 has the highest peak discharge of 368 $m^3/s$ (see Table 2). Thus the information obtained from the local community confirms the validity of the stream flow data obtained from the hydrological records.

The measured inundated distance by the year 2000 flood was approximately 102 m away from the river, whereas the measured inundated distance by the year 1977 flood was approximately 48 m away from the river. This confirms that the 1977 flood was much smaller than the year 2000 flood which must therefore have been of a return period much greater than 200 which was also exceeded by the 1977 flood from Log Pearson Type III distribution computations (see Table 2). The return period of the year 2000 flood simulated in the neighbouring catchments of the Sabie River by Smithers et al. (2001) exceeded 200 in parts of the catchment confirming that of the study area as would have been estimated by Log Pearson Type III distribution to be possibly in excess of the same return period of 200.

The designated average width of 1:50 year flood line has been established to be 55 m from the river bank whereas that for 1:100 year flood line is 100 m from the river bank. The distance measured inland from the river to the settlements was 60 m. The settlements therefore are slightly out of the 1:50 year flood line but are within the 1:100 year flood line. Although the extent of the year 2000 flood was measured at 102 m in the lower areas, the first line of settlements were not inundated. This is because the first line of settlements is located on an elevated neighbourhood of the river. Therefore the community can be considered to be safe from the risk of extreme floods of magnitudes and return periods that have occurred in the Luvuvhu River basin at Makovha village. This fact is validated further by the fact that from the stream flow data analysis by Log Pearson Type III distribution the 1977 flood had a return period of greater than 200 years but only flooded up to a measured distance of 48 m. It is, however, important to point out that this may not necessarily hold true for all extreme floods for some may be of greater magnitude than the 2000 flood and may end up inundating the settlements. The 2000 flood itself nearly submerged the settlements beyond the 100-year flood mark. It thus caused extensive damage to crops in general in the riparian zone.

From the information received from the interview with the local community which led to the measurement of the flooded distance of 48 m for the year 1977 flood, Log Pearson Type III distribution could have overestimated the return period. The expected distance should have exceeded 100 m away from the river which is the designated flood mark for 1:100 year flood. However, the distance moved inland by the flood is a function of a number of factors including the depth of the river, the width of the river, the infiltration rate of the soil and the elevation change as one moves away from the river. The flow could also have been overestimated or the peak flow was the first discharge after the dry period and most of it filled the river channel and infiltrated in the immediate banks of the river. Thus the reasonableness of the statistical analysis of flood frequency can be verified by measuring the distance reached inland by the flood from the river bank.

The impact of the 1977 and the year 2000 floods confirm that agriculture in the neighbourhood of the riparian zone and the first line of settlements should be located beyond the 1:50 flood line and the 1:100 flood line respectively. Permanent dwellings can be located between the 1:50 flood line and 1:100 flood line if the elevation permits it as in the case of Makovha village. However, the practicing of agriculture in the neighbourhood of the riparian zone should be flexible during periods of no large and extreme floods, provided erosion protection measures are in place to protect the river from sedimentation. This is in response to the scarcity of agricultural land for the community residing near the river beyond the riparian zone and availability of good soil fertility in the neighbourhood of the riparian zone.

The farming carried out in the neighbourhood of the riparian zone involves growing seasonal crops such as maize and water melon. The farming therefore lasts for a short season and therefore can be planned and scheduled in relation to predicted recurrence intervals of potentially destructive floods.

The frequency factors associated with the highest peak annual discharge of the year 1977 and the lowest peak annual discharge of the year 1983 are 3.18 and -1.99 respectively and which fall outside the upper and the lower limits respectively in the Harter's Tables for a skew coefficient of 0.5 (see Table 1). The return period of the year 1977 flood therefore exceeds the range in Harter's Tables and has therefore been taken as >200 years (Table 2). Similarly, the return period for the year 1983 flood falls below the range in the Harter's Tables and has therefore been taken to be less than 1 (Table 2).

**Table 1: The mean, the standard deviation and the skewness coefficient for Log Q**

| **Parameters** | **Value** |
|---|---|
| Mean (M) | 1.081 |
| Standard deviation (S) | 0.467 |
| Skew coefficient (G) | 0.500 |

**Table 2: Stream flow data and Log Pearson Type III computed return periods**

| Year | Annual peak discharge(Q) ($m^3/s$) | Return period (Tr) | Year | Annual peak discharge(Q) ($m^3/s$) | Return period (Tr) |
|---|---|---|---|---|---|
| 1950 | 8.62 | 1.8 | 1975 | 40.70 | 8.0 |
| 1951 | 6.74 | 1.6 | 1976 | 53.60 | 15.4 |
| 1952 | 8.62 | 1.8 | 1977 | 368.00 | >200.0 |
| 1953 | 8.62 | 1.8 | 1978 | 26.50 | 4.7 |
| 1954 | 8.62 | 1.8 | 1979 | 16.20 | 3.2 |
| 1955 | 8.62 | 1.8 | 1980 | 17.00 | 3.3 |
| 1956 | 8.62 | 1.8 | 1981 | 33.30 | 6.3 |
| 1957 | 8.62 | 1.8 | 1982 | 2.53 | 1.0 |
| 1958 | 8.62 | 1.8 | 1983 | 1.42 | <1 .0 |
| 1959 | 8.68 | 1.8 | 1984 | 7.29 | 1.6 |
| 1960 | 23.10 | 4.3 | 1985 | 6.82 | 1.6 |
| 1961 | 23.50 | 4.4 | 1986 | 2.44 | 1.0 |
| 1962 | 23.00 | 4.3 | 1987 | 8.73 | 1.8 |
| 1963 | 4.13 | 1.2 | 1988 | 29.40 | 5.2 |
| 1964 | 6.50 | 1.5 | 1989 | 8.42 | 1.8 |
| 1965 | 1.64 | 1.0 | 1990 | 3.50 | 1.1 |
| 1966 | 38.30 | 7.5 | 1991 | 13.80 | 2.7 |
| 1967 | 27.40 | 4.8 | 1992 | 12.10 | 2.3 |
| 1968 | 7.19 | 1.6 | 1993 | 16.00 | 3.2 |
| 1969 | 34.20 | 6.6 | 1994 | 4.27 | 1.2 |
| 1970 | 2.00 | 1.0 | 1995 | 16.60 | 3.3 |
| 1971 | 4.99 | 1.3 | 1996 | 60.70 | 14.5 |
| 1972 | 60.20 | 14.3 | 1997 | 9.49 | 1.9 |
| 1973 | 5.66 | 1.4 | 1998 | 9.93 | 1.9 |
| 1974 | 77.80 | 20.4 | 1999 | 25.40 | 4.6 |

## 4 Conclusion

Interviews with the local community indicate that large and extreme floods with destructive tendencies are infrequent at Makovha village along Luvuvhu River. This has been corroborated with the results of flood frequency analysis of stream flow from a gauging station at Makovha village along the Luvuvhu River using Log Pearson Type III distribution. The results of the analysis show that floods with return periods in excess of 50 years are rare. However, when they occur such as in the year 1977 and the year 2000, they destroy plants along the riparian zone and crops in the neighbourhood and have also threatened to destroy human settlements particularly in the low elevation areas in the neighbourhood of the riparian zone. The study has identified the potential to practice agriculture in the neighbourhood of the fertile riparian zone in the periods in between risky and destructive floods provided proper forecasting of destructive floods and soil erosion management practices are adhered to.

The study established that Log Pearson Type III distribution tends to overestimate the return periods of annual maximum peak flood events and the reasonableness of its return period estimates can be determined by measuring the distance of the flooded neighbourhood of the riparian zone from the river bank.

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## References

Alexander, W.J.R. 1990 Flood hydrology for Southern Africa, SANCOLD, Pretoria, 560 pp

Alexander, W.J.R. 2000 Flood risk reduction measures, revised first edition, University of Pretoria, Department of Civil Engineering

Linsley, R.K 1988 Hydrology for Engineers, SI Metric Edition, McGraw-Hill Book Company, London, UK, 210 pp

Luna, L.B. 1997 Water, rivers, creeks, University Science books, United States of America, 208 pp

Smithers, J.C, Schulze, R.E, Pike, A and Jewitt, G.P.W 2001 A hydrological perspective of the February 2000 floods: A case study of the Sabie River Catchment, School of Bioresources and Environmental Hydrology, University of Natal, Pietermaritzburg, 325-332

Van Bladeren, D. and Zawada, P. 1998 Paleoflood hydrology: A management tool for South African Rivers, Council for Geoscience, Pretoria, RSA